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SOLAR POWER SATELLITE ANTENNA PHASE CONTROL SYSTEM

HARDWARE SIMULATION PHASE IV

VOLUME III. SOLARSIM USERS MANUAL

PREPARED FOR

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CONTRACT NO. NAS9-16097

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1. SOLARSIM COMPUTER SIMULATION DEVELOPMENT

SOLARSIM is a software package designed to predict the effect of certain electrical and mechanical imperfections of the SPS system on its performance. The following is a documentation of the SOLARSIM programs and SOLARSIM capabilities to quantify the spacetenna performance parameter values. The overall set up of SOLARSIM computer simulation is shown in Figure 1.1. As shown in the figure, the user input directs the central processor unit to pick the correct SOLARSIM subroutine from the subroutine package stored in the computer memory. Every operation done by the SOLARSIM is interactive in nature, i.e., questions are asked and the user answers control the execution of the programs. As shown in the Figure 1.1, the SOLARSIM package can compute the following quantities:

1. RMS Pointing error (PE)
2. Tilt effects (TILT)
3. MPTX code tracking loop performance (CDTL)
4. MPTX carrier tracking loop performance (CRTL)
5. Averaged power pattern (APP)
6. Power transfer efficiency (PTE)

There are two different types of inputs necessary for the operation of SOLARSIM routines, user inputs and the computer generated inputs. As mentioned earlier, the user inputs have the prompting, i.e., it is an interactive software, but the computer inputs are automatic in the sense that once the user's input specifies the SOLARSIM subroutine, the subroutine calls for the necessary computer generated input for its execution.

The SOLARSIM programs are configured such that all the user has to know is the set of inputs to the program he desires to execute.

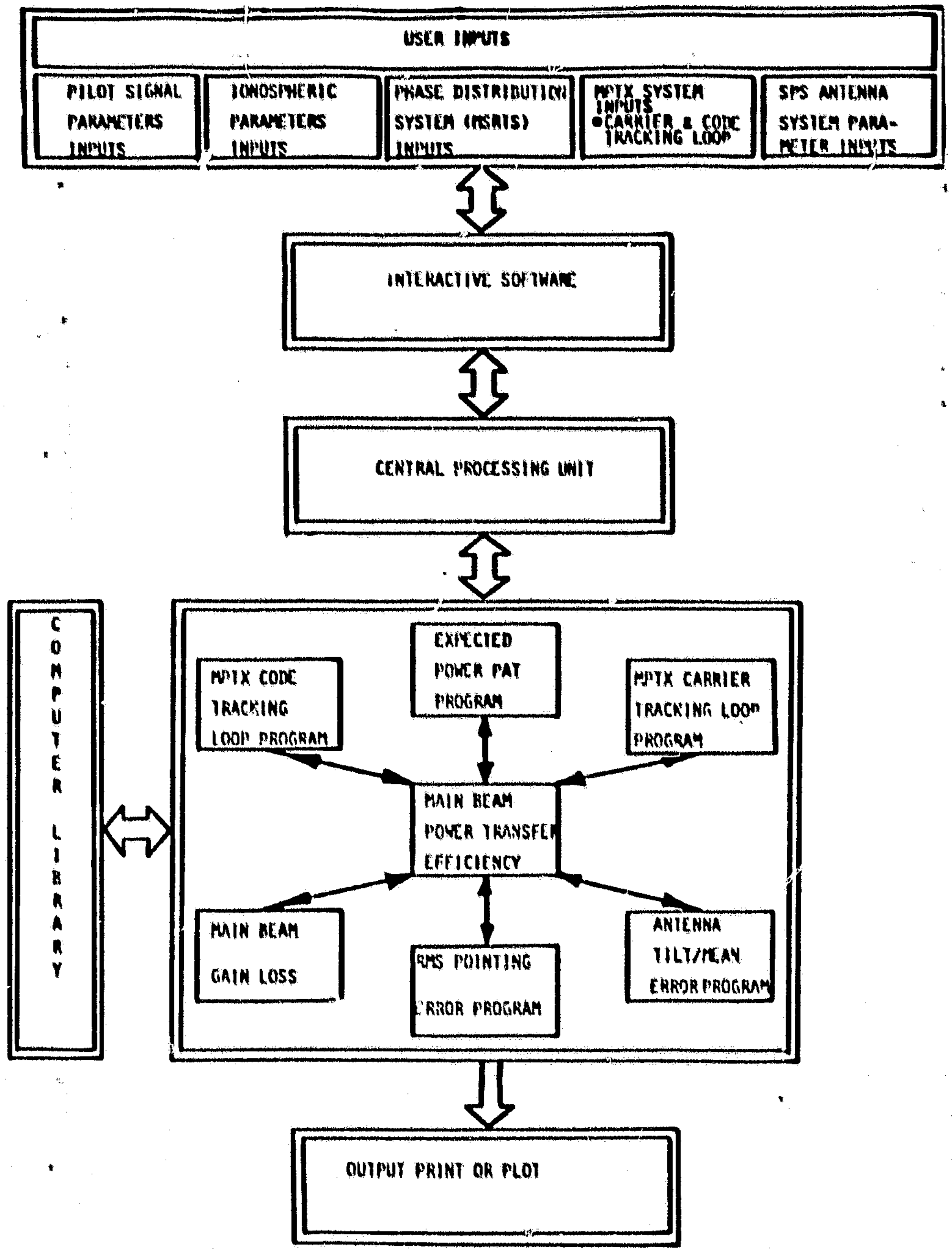


Fig. 1.1. SOLARSIM COMPUTER SIMULATION PACKAGE.

POWER DENSITY STEP	NUMBER OF SUBARRAYS	NUMBER OF POWER MODULES PER CONJUGATION PT.	TOTAL # OF POWER MODULES PER DENSITY STEP
1	276	36	9936
2	632	30	18960
3	644	24	15456
4	628	20	12560
5	784	16	12544
6	900	12	10800
7	664	9	5976
8	612	8	4896
9	1052	6	6312
10	1028	4	4112
TOTAL FOR FULL ARRAY	7220		101552

SIZE OF THE SUBARRAY = 10.4m x 10.4m

POWER DENSITY STEP	SIZE OF SUBARRAY	NUMBER OF SUBARRAYS	TOTAL # OF POWER MODULES PER CONJUGATION POINT	# OF POWER MODULES
1	1.73mx1.73m	9936	1	9936
2	1.89mx1.89m	18960	1	18960
3	2.12mx2.12m	15456	1	15456
4	2.32mx2.32m	12560	1	12560
5	2.6 mx2.6 m	12544	1	12544
6	3. m x3. m	10800	1	10800
7	3.46mx3.46m	5976	1	5976
8	3.67mx3.67m	4896	1	4896
9	4.24mx4.24m	6312	1	6312
10	5.2 mx5.2 m	4112	1	4112
		101552		101552

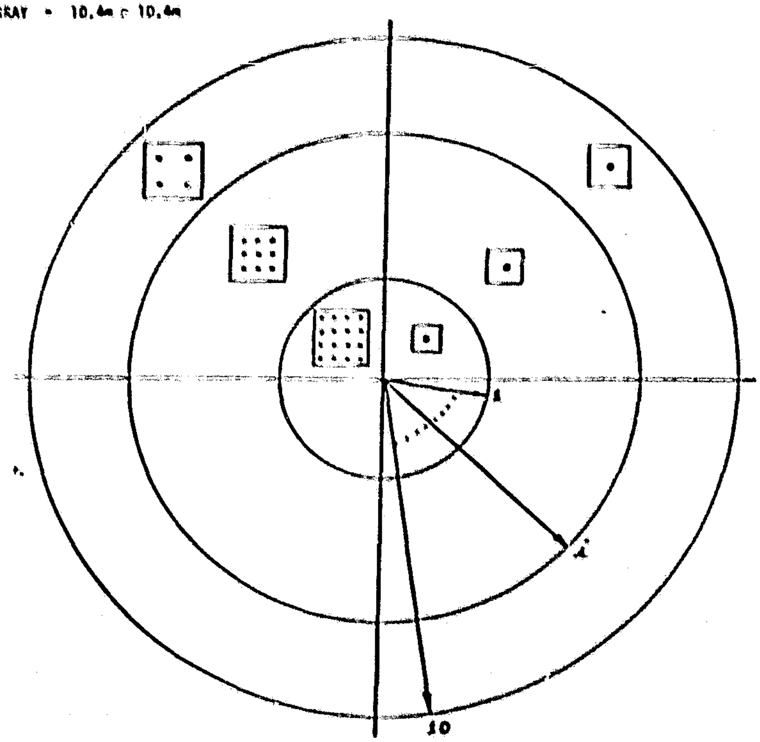


Fig. 2.1 VARIABLE AND FIXED SIZE SUBARRAY.

Following is an attempt to make the user familiar with the assumptions and general requirements of the SOLARSIM package.

2.0 SOLARSIM SPS SYSTEM DEFINITION AND COMPUTATIONAL CONSIDERATIONS

2.1 Spacetenna

Spacetenna is a stepped approximation of a circle of 11 cm in diameter having an ara of 0.76 km^2. This area is subdivided into square subarrays totaling 101,552 = N. The operation of the spacetenna being retrodirective, it needs a pilot beam originating at the center of the rectenna which is used to phase the downlink power beam to achieve retrodirectivity. The convention followed is (θ_r, ϕ_r) as the direction of the pilot reference signal as seen from the spacetenna center.

2.2 Current Taper

For the control of the power lost in the sidelobes of the antenna pattern, an excitation current taper of 10 dB (center to edge) is suggested. This taper is implemented by discretizing it into ten distinct levels and putting different numbers of amplifiers (klystron tubes) from level to level. It should be remembered that the ratings of all the amplifiers is the same all over the spacetenna. The ten levels when imposed over the circular spacetenna become ten circles with different diameters and having a different number of amplifiers per unit area from circle to circle. Figure 2.1 shows the spacetenna with ten power density circles, their radii and the number of klystrons in each circle. Even though the current rating of the klystron is the same, the current density is different in different power rings. The feed currents also have amplitude jitters associated with them. These two quantities are designated by:

CURNT(I) Current densities in the I^{th} power ring, I=1,...,10

SIGNAL(I) Amplitude jitter in the I^{th} power ring, I=1,...,10

2.3 Subarrays

The baseline system assumes only one power amplifier per subarray. Since there are different numbers of amplifiers present per unit area in different power density rings, the size of subarray is different from ring to ring. The subarrays are assumed to be square and have the power amplifier and the phase conjugation circuitry at its geometric center. The actual radiating elements are the slots in the waveguides. Figure 2.1 shows the size and number of subarrays in each power ring. One alternate way is to have a constant sized square subarray throughout the spacetenna. Such an arrangement will have a different number of power amplifier per subarray from ring to ring. This arrangement is also shown in Figure 2.1. The following convention is adapted:

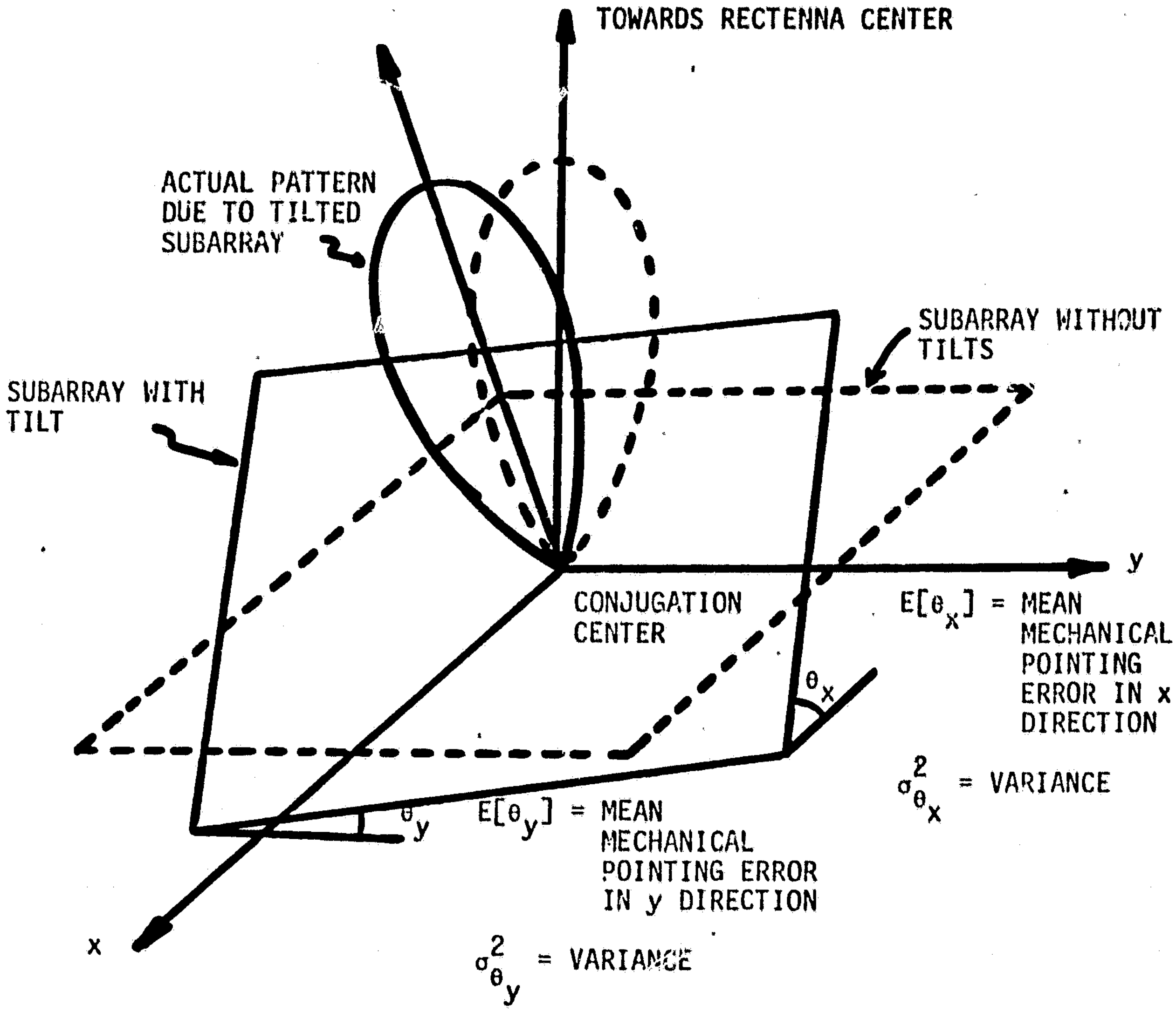
N(I) The number of radiating slots in i^{th} power ring I=1,...,10

M(I) The number of radiating slots per subarray in i^{th} power ring, I=1,...,10)

2.4 Tilts on Subarrays

There are basically one type of tilt and two types of jitters associated with the subarrays which are, mechanical tilting of the subarrays with the associated jitters and the radiating and transmiting element location jitters. The mechanical tiliting of the subarrays can be considered to have two components, i.e, the x-component and the y-component the mean values of which gives the mechanical tilt of the spacetenna with respect to the perfectly pointing spacetenna. The radiating and transmitting element location jitters actually have three

Fig. 2.2. EFFECTS OF SUBARRAY MEAN TILTS AND JITTER



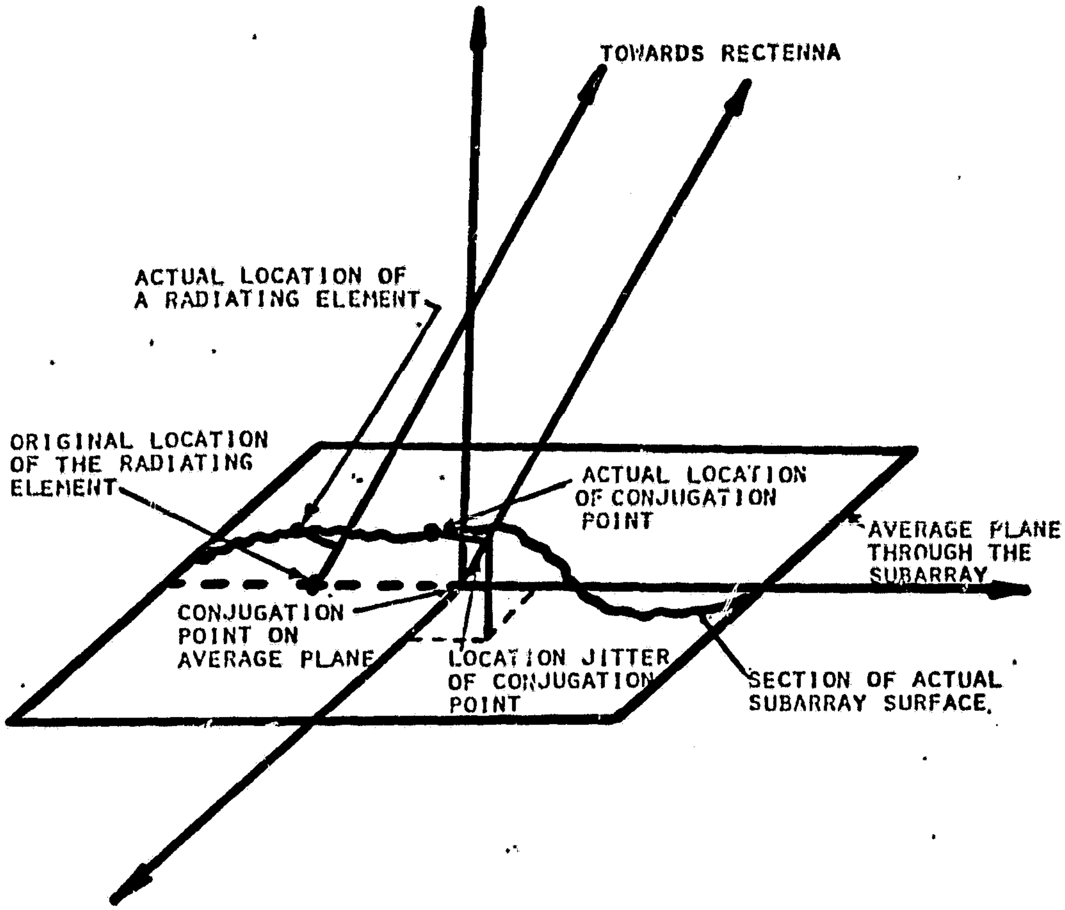


Fig. 2.3. JITTERS ADDED DUE TO LOCATION UNCERTAINTY OF RADIATING AND CONJUGATION POINTS.

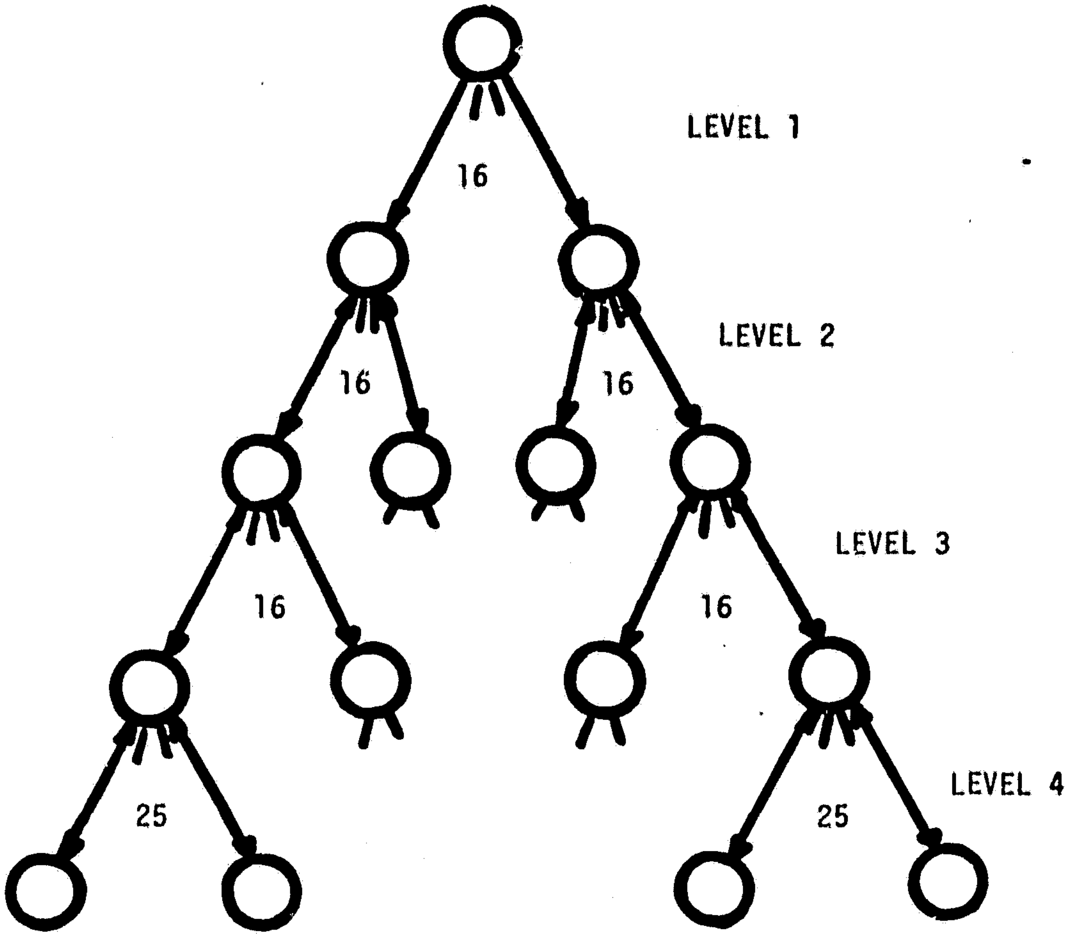
components: two components in the plane perpendicular to the line forming that particular element and the rectenna center and one component along that line. We will neglect the jitter components in the plane mentioned above and consider only the jitter component along the line joining the element and the rectenna center as the location jitter of that particular element. The convention followed is given in the following table:

Mean Mechanical Tilts of the Subarrays	$X_{MEAN}(I), Y_{MEAN}(I)$ I = 1,2,...,10
Jitters on Mechanical Tilts	SIGMA(I), I=1,2,...,10
Location Jitter on the Pilot Receiving Element	SIGPSI(I), I=1,2,...,10
Location Jitter on the Radiating Element	SIGPHI(I), I=1,2,...,10

It should be noted that X_{MEAN} as well as Y_{MEAN} are in minutes while the location jitters will be specified in terms of % of the wvelength of the power wave. Figures 2.2 and 2.3 show these tilts and jitters.

2.5 Phase Control System

Since the operation of the spacetenna is retrodirective, it needs a constant phase reference throughout the antenna for conjugator to function properly. This constant phase is supplied to the conjugators by the use of MSRTS in the form of a tree. The master oscillator situated at the physical center of the spacetenna locks onto the phase of the incoming pilot signal. This phase is transmitted to 16 first level slave oscillators, each of these sends the phase to 16 second level slave oscillators. These third level slaves in turn send the phase to 25 fourth level slaves. Figure 2.4 shows the phase distribution tree.



- PHASE NOISES ARE CORRELATED
- POWER SPLITTERS, POWER TRANSPONDERS, PHASE TRACKING PLLS, MULTIPLIERS, MICROWAVE HARDWARE COMPONENTS

Fig. 2.4. FOUR LEVEL PHASE DISTRIBUTION TREE.

As the master phase passes from level to level of the phase distribution tree structure it gets corrupted by the phase noise added by the oscillators and the related equipment at each level. The variance of the accumulated noise is designated as SIGMAB(I), at the end of the distribution tree.

2.6 Inputs for the Double Integrator Subroutine Supplied by the Computer Library "Math Pack"

The description of these inputs is necessary for the power transfer efficiency program only because a double integration of the averaged power pattern is necessary to obtain the total power radiated by the spacetenna and the power received by the rectenna. The following formula will illustrate the inputs necessary for the program:

$$\text{Power Received on Area 'A'} = \int_{\theta_L}^{\theta_u} \int_{\phi_L}^{\phi_u} APP(\theta,\phi) \sin \theta d\theta d\phi$$

where $APP(\theta,\phi)$ is the averaged power pattern produced by the spacetenna. Where

θ_L, θ_u: The lower and upper limits of the variable θ describing the area A.

ϕ_L, ϕ_u: The lower and upper limits of the variable ϕ describing the area A.

Note: To obtain the power received by the rectenna $\theta_L=0$, $\theta_u = 0.477'$, $\phi_L = 0$ and $\phi_u = 360^o$.

The double integral subroutine approximates the above double integral by the following double sum

$$\int_{\theta_L}^{\theta_u} \int_{\phi_L}^{\phi_u} APP(\theta,\phi)\sin \theta d\theta d\phi \cong \sum_{k=1}^{I_\theta} \sum_{t=1}^{I_\phi} \sum_{i=1}^{N_\theta} \sum_{j=1}^{N_\phi} W_{\theta i} W_{\phi j} APP(\theta_{ki},\phi_{tj}) \sin \theta ki$$

where

I_θ, I_ϕ: Are the number of intervals on the θ axis and ϕ axis respectively, on the specified θ and ϕ ranges.

N_θ, N_ϕ: Number of points in each of I_θ and I_ϕ respectively in the θ and ϕ ranges.

$W_{\theta i}$, $W_{\phi j}$, θ_{ki} and ϕ_{tj} are generated by the subroutine and does not have to be supplied.

Note: A reasonable input for I_θ, I_ϕ would be 3,3 and for N_θ, N_ϕ would be 4,4.

3. USAGE OF SOLARSIM SUBROUTINES

SOLARSIM subroutine package is created such that user encounters minimum of trouble to run it. After a few preliminary commands from the user, the entire operation becomes automatic stopping and asking questions where user input is necessary. User is prompted for all the inputs necessary for that particular program; thus, virtually eliminating all user generated errors in data feeding. The preliminary commands preparing the SOLARSIM subroutine package for user selection of program are necessary only once, making selecting and running of subsequent programs easy. The preliminary commands necessary are shown in the following computer printout. As seen on that sheet the last command is @XQT LINCOM.SELECT. This executes the 'select' subroutine which shows that there are six choices possible. They are: Averaged Power Pattern, Power Transfer Efficiency, Pointing Error, Tilt Affects, Carrier Tracking Loop and the Code Tracking Loop. @ ADD.LINCOM. Abbreviated File Name is the command necessary to access the required subroutine from the magnetic tape which was loaded on the tape drive

```
@RUN ZTHD3,E/3205,E-N03737

DATE: 011381     TIME:  172030

@JSC*CALLUP.TAPES N03737*ZTHD3.,X09676/W

REQUEST HAS BEEN ACCEPTED

@ASG,T SPS.,8C,X09676

READY

@ASG,T LINCOM.

READY
>@REWIND SPS.

FURPUR 27R3A      E35 SL73R1 01/13/81 17:33:52
>@COPIN SPS.,LINCOM.

 6 SYM  1 ABS
>@XQT LINCOM.SELECT

 THERE ARE SIX PROGRAMS AVAILABLE : AVERAGED, POWER PATTERN,POWER TRANSFER EFFICIENCY
 POINTING ERROR,TILT EFFECTS,CARRIER TRACKING , LOOP AND THE CODE TRACKING TRACKING LOOP

 THEY WILL BE ABBREVIATED AS : APP,PTE,PE,TILT, CRTL AND CDTL RESPECTIVELY

 TO EXECUTE THE REQUIRED PROGRAM TYPE, @ADD LINCOM.ABBREVIATED PROGRAM FILE NAME
>
```

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before. As mentioned befcre, this set of commands are necessary only once, at the start of the computer run. Keeping this in mind we will describe each subroutine one by one.

3.1 SOLARSIM Subroutine Pointing Error (PE)

Purpose: SOLARSIM subroutine POINTING ERROR evaluates the effect of phase error introduced by the phase distribution tree (at various levels of the tree) onto the pointing error. It also allows variations in number of levels and number of branches per node at each level of the phase distribution tree. This subroutine may also be used for determining effects of other phase error sources on the pointing error. An example of this would be the phase error introduced by the SPS transponder circuitry can be counted as the pahse error due to the last level of the phase distribution tree.

Access Command: @ ADD LINCOM.PE

Inputs: The only necessary inputs are:

Number of levels in the phase distribution tree (PDT)

Number of power density levels

Number of branches per node at each level of PDT

Outputs: The following page shows a sample run of the program.

```
@ADD LINCOM.PE
PURPUR 27R3A       E35 SL73R1 01/13/81 17:35:19
READY
PURPUR 27R3A       E35 SL73R1 01/13/81 17:35:28
 2 SYM  1 REL  1 ABS

 ENTER THE NUMBER OF PHASE DISTRIBUTION TREE LEVELS  AND THE NUMBER OF POWER DENSITY LEVELS
>4,10

 ENTER THE NUMBER OF BRANCHES PER NODE
>16,16,16,25

 ENTER 1 FOR POINTING ERROR FOR SUPPLIED   PHASE ERRORS PER LEVEL OF THE PHASE DISTRIBUTION TREE
 OR ENTER 2 FOR POINTING ERROR FOR VARIABLE  TOTAL RMS PHASE ERROR
>2

 ENTER THE STEP SIZE AND NUMBER OF TERMS NECESSARY  FOR THE TOTAL RMS PHASE ERROR
 IN THE PHASE DISTRIBUTION TREE
>1.0,20

      BRANCHING OF THE PHASE DISTRIBUTION TREE:
        16         16         16         25

     TOTAL RMS PHASE ERROR(DEGREES)    POINTING ERROR (MINUTES)
                .00000000                  .00000000
               1.00000000                  .00110421
               2.00000000                  .00220842
               3.00000000                  .00331263
               4.00000000                  .00441683
               5.00000000                  .00552104
               6.00000000                  .00662525
               7.00000000                  .00772946
               8.00000000                  .00883367
               9.00000000                  .00993788
              10.00000000                  .01104209
```

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```
-----------          ---------
13.00000000          .01435471
14.00000000          .01545892
15.00000000          .01656313
16.00000000          .01766734
17.00000000          .01877155
18.00000000          .01987576
19.00000000          .02097996

ENTER 1 FOR A NEW RUN OR 2 TO TERMINATE THE RUN
>2
* *FLOATING PT-UNDRFLO HAS OCCURRED* *
* *REGISTERS HAVE BEEN ZEROED* *
>
```

3.2 SOLARSIM Subroutine TILT

Purpose: SOLARSIM subroutine TILT evaluate the effect of various tilts of the subarrays, the location jitters of the power radiating and pilot receiving elements and finally the phase distribution system errors on the gain of the spacetenna.

Access Command: @ ADD LINCOM.TILT

Inputs:

CURNT(I)	I = 1,...,10
N(I)	I = 1,...,10
M(I)	I = 1,...,10
SIGPSI(I)	I = 1,...,10
SIGPHI(I)	I = 1,...,10
YMEAN(I)	I = 1,...,10
XMEAN MAX	Maximum XMEAN tilt in minutes
SIGMA(I)	I = 1,2,...,10

Note that this program does need the integrator subroutine to generate the weights. One needs to know the above inputs only if values different from baseline values are to be fed to the program.

Outputs: The following pages show a sample run of the program.

```
@ADD LINCOM.TILT
FURPUR 27R3A       E35 SL73R1 01/13/81 17:38:42
READY
FURPUR 27R3A       E35 SL73R1 01/13/81 17:39:00
 6 SYM  4 REL  1 ABS


 INPUTS FOR THE TILT PROGRAM BEGIN

 PRINT 1 FOR USING THE BASELINE CURRENT TAPER OR  2 FOR DIFFERENT TAPER
>1

 ENTER 1 FOR USING BASELINE FOR NUMBER OF SLOTS PER POWER RING OR 2 FOR DIFFERENT NUMBER OF SLOTS
>1

 ENTER 1 FOR USING BASELINE FOR NUMBR OF  SLOTS PER SUBARRAY IN EACH POWER RING OR 2 FOR DIFFERENT NUMBER OF SLOTS
>1

 ENTER 1 FOR SAME LOCATION JITTERS ON THE RADIATING ELEMENTS IN ALL POWER RINGS OTHERWISE ENTER 2
>1

 ENTER THE COMMON LOCATION JITTER OF THE RADIATING ELEMENTS IN TERMS OF % OF LAMBDA
>0.0

 ENTER 1 FOR SAME LOCATION JITTER ON THE CONJUGATION POINT IN ALL POWER RINGS OTHERWISE ENTER 2
>1

 ENTER COMMON LOCATION JITTER FOR THE CONJIGATION  POINT
>0.0

 ENTER 1 FOR SAME X AND Y TILTS FOR SUBARRAYS OTHERWISE ENTER 2
>1

 ENTER THE MAXIMUM TILT FOR X AND Y DIRECTIONS
>20.0

 ENTER 1 FOR SAME TILT JITTER FOR EACH POWER   RING OTHERWISE ENTER 2
>1

 ENTER THE COMMON JITTERS ON TILTS
>2.0

 ENTER THE NUMBER OF POINTS DESIRED ON X-AXIS
>20
```

INPUTS FOR TILT PROGRAM COMPLETE

X&Y TILT (MINUTES)	(G/G0) %	G/G0 IN DB
.00000000	99.85770130	-.00618432
.99999433	99.82218361	-.00772931
1.99998876	99.71570778	-.01236422
2.99998331	99.53852844	-.02008782
3.99997815	99.29104519	-.03089918
4.99997330	98.97384453	-.04479558
5.99996895	98.58765316	-.06177469
6.99996501	98.13335609	-.08183345
7.99936173	97.61200237	-.10496774
8.99995911	97.02478409	-.13117314
9.99995720	96.37302971	-.16044484
10.99995625	95.65822220	-.19277693
11.99995625	94.88196564	-.22816325
12.99995708	94.04599380	-.26659697
13.99995911	93.15216064	-.30807066
14.99396233	92.20243931	-.35257586
15.99996686	91.19889355	-.40010427
16.99997234	90.14369488	-.45064642
17.99997997	89.03910637	-.50419205
18.99998856	87.88746357	-.56073068

ENTER 1 FOR FRESH RUN OR 2 FOR TERMINATION
>2

>

3.3 SOLARSIM Subroutine Power Pattern (APP)

Purpose: The purpose of this subroutine is to study the effects of parameters like the subarray tilts, the phase jitters, current amplitude jitter, etc. on the power pattern produced by the spacetenna.

Access Command: @ ADD LINCOM.APP

Inputs:

N(I)	I = 1,...,10
M(I)	I = 1,...,10
NA(I)	I = 1,...,10
R(I)	I = 1,...,10
SIGMAB(I)	I = 1,...,10
SIGPSI(I)	I = 1,...,10
SIGPHI(I)	I = 1,...,10
SIGMAI(I)	I = 1,...,10
CURNT(I)	I = 1,...,10
XMEAN(I)	I = 1,...,10
SIGMA(I)	I = 1,...,10
PHI	The value of ϕ direction in which the pattern is generated.
NTERM	The number of θ value at which the pattern will be evaluated.
STEP	The step size for θ evaluation.

Note that the parameter values N(I), M(I), and R(I) are required to be fed into the program only if these values are different from the baseline values. All the necessary baseline values are already present in the program. Of course, NTERM and STEP will be required to be fed in by the user.

Output: The following pages show a sample run of the subroutine APP. In this particular run the total rms phase error is assumed to be 10^{o} (input) while all the other inputs were held at zero. It should be noted that the program also produces the power output. This output is true for the SPS at 36,000 km from the surface of the Earth.

```
@ADD LINCOM.APP
FURPUR 27R3A       E35 SL73R1 03/18/81 11:48:50
READY
FURPUR 27R3A       E35 SL73R1 03/18/81 11:49:05
 8 SYM  5 REL  1 ABS

 ENTER APP FOR THE AVERAGED POWER PATTERN OR PTE FOR POWER TRANSFER EFFICIENCY:
>APP

 INPUTS FOR THE POWER PATTERN PROGRAM BEGIN

 ALL THE FOLLOWING QUESTIONS SHOULD BE  ANSWERED IN YES OR NO OR GIVE THE DATA:

 DO YOU WANT BASELINE NUMBER OF POWER DENSITY STEP?
>YES

 DO YOU WANT THE BASELINE CURRENT TAPER?
>YES

 DO YOU WANT THE BASELINE NUMBER OF SLOTS PER POWER RING?
>YES

 DO YOU WANT BASELINE NUMBER OF SLOTS PER  SUBARRAY IN EACH POWER RING?
>YES

 DO YOU WANT THE SAME LOCATION JITTER ON THE  RADIATING ELEMENTS IN ALL POWER RINGS?
>YES

 ENTER THE COMMON LOCATION JITTER OF THE RADIATING ELEMENTS IN TERMS OF  % OF LAMBDA:
>0.0

 DO YOU WANT THE-SAME-LOCATION-JITTERS ON THE CONJUGATION POINTS IN ALL THE POWER RINGS?
>YES

 ENTER THE COMMON LOCATION JITTER OF THE  CONJUGAION POINTS IN ALL THE POWER RINGS IN % OF LAMBDA:
>0.0

 IN EACH POWER RING THE MEAN X AND MEAN Y  TILTS WILL BE ASSUMED SAME:

 DO YOU WANT SAME MEAN VALUES FOR X AND Y TILTS IN DIFFERENT POWER DENSITY RINGS?
>YES

 ENTER THE COMMON MEAN X AND Y TILTS  IN MINUTES:
>0.0
```

```
DO YOU WANT SAME TILT JITTERS FOR THE  SUBARRAYS IN ALL POWER RINGS?
>YES

ENTER THE COMMON TILT JITTERS IN MINUTES FOR SUBARRAYS IN THE SPACETENNA:
>0.0

DO YOU WANT THE SAME AMPLITUDE JITTER FOR ALL THE POWER RINGS?
>YES

ENTER THE COMMON AMPLITUDE JITTER OF  ALL THE AMPLIFIERS IN PER UNIT VALUE:
>0.0

ENTER THE TOTAL PHASE JITTER IN DEGREES  AT THE END OF PHASE DISTRIBUTION TREE:
>10.0

ENTER THE PILOT WAVE DIRECTIONS, THETA IN MINUTES AND PHI IN DEGREES:
>0.0,0.0

 THETAR =  .00000000       PHIR =  .00000000
 M(I) =         395       526       607       729      1002      1335      1618      1821      2427      3632
 N(I) =     3918749   9968491   9376400   9145204  12558637  14414030   9667592   8912205  15316727  14970175
 NA(I) =       9936     18960     15456     12560     12544     10800      5976      4896      6312      4112
 R(I) =    .9776+02  .1773+03  .2318+03  .2747+03  .3203+03  .3658+03  .3960+03  .4219+03  .4630+03  .5000+03
 SIGPSI(I)=   .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000
 SIGPHI(I)=   .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000
 SIGMAI(I)=   .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000
 CURNT(I)= .1000+01  .9129+00  .8164+00  .7454+00  .6666+00  .5773+00  .5000+00  .4714+00  .4083+00  .3333+00
 XMEAN(I)=    .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000
 SIGMA(I)=    .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000     .0000
 D(I) =    .1738+01  .1904+01  .2129+01  .2332+01  .2604+01  .3014+01  .3477+01  .3687+01  .4258+01  .5215+01
 SIGMAB =     .1000+02

ENTER THE VALUE OF PHI IN DEGREES:
>0.0

ENTER THE NUMBER OF TERMS NECESSARY:
>20

ENTER THE STEP SIZE IN MINUTES:
>1.0
```

NORMALIZING FACTOR = .4002902138+16

THETA (MINUTES)	NORMALIZED PATTERN (DB)	POWER DENSITY (MIL WATT/CM*CM)
.0000	.0000	.2291+02
.1000+01	-.5799+02	.3642-04
.2000+01	-.4282+02	.1196-02
.3000+01	-.4470+02	.7758-03
.4000+01	-.4965+02	.2483-03
.5000+01	-.4860+02	.3161-03
.6000+01	-.6262+02	.1253-04
.7000+01	-.6145+02	.1639-04
.8000+01	-.6192+02	.1474-04
.9000+01	-.4955+02	.2541-03
.1000+02	-.5102+02	.1811-03
.1100+02	-.6359+02	.1003-04
.1200+02	-.5710+02	.4464-04
.1300+02	-.5482+02	.7559-04
.1400+02	-.6327+02	.1080-04
.1500+02	-.6491+02	.7400-05
.1600+02	-.6241+02	.1317-04
.1700+02	-.6177+02	.1524-04
.1800+02	-.615[illegible]2	.1608-04
.1900+02	-.6462[illegible]2	.7907-05

DO YOU WANT A FRESH RUN?
>NO

3.4 SOLARSIM Subroutine Power Transfer Efficiency (PTE)

Purpose: The purpose of SOLARSIM subroutine power transfer efficiency is to study the effects of perturbations, mechanical or otherwise, on the power transfer efficiency of the spacetenna.

Access Command: @ ADD LINCOM.PTE

Inputs: If the program is run for the baseline quantities then the following quantities are not necessary but if they are to be different from baseline numbers one needs it for the input of the program.

N(I)	I = 1,...,N
M(I)	I = 1,...,N
NA(I)	I = 1,...,N
R(I)	I = 1,...,N
SIGMAB(I)	I = 1,...,N
SIGPSI(I)	I = 1,...,N
SIGPHI(I)	I = 1,...,N
SIGMAI(I)	I = 1,...,N
CURNT(I)	I = 1,...,N
XMEAN(I)	I = 1,...,N
SIGMA(I)	I = 1,...,N
(θ_r, ϕ_r)	The pilot incidence angles as seen from the spacetenna.
Xa,Xb	Lower and upper limits of theta integration in minutes.
Ya,Yb	Lower and upper limits of phi integration in degrees.

Nx,Ny Number of points to be used per interval in the Gauss Quadrature approximatin of the integral

Ix,Iy Number of intervals in the theta and phi range to be considered for the integration.

Output: The following pages indicate the computer run for the Power Transfer Efficiency Program. In this particular run the location jitters on the radiating and receiving elements as well as the current amplitude jitters are constants for the spacetenna, i.e., they do not change from power ring to power ring. In such a case the program has the capability of looping back and changing the initial conditions of the parameters. As seen from the printout, the program is run for different initial conditions for the parameters. Any one of the parameters is allowed to vary producing a set of values for the efficiency holding all other parameters to constant values.

```
@ADD LINCOM.PTE
FURPUR 27R3A        E35 SL73R1 03/18/81 10:34:40
READY
FURPUR 27R3A        E35 SL73R1 03/18/81 10:34:52
 8 SYM  5 REL  1 ABS

 ENTER APP FOR THE AVERAGED POWER PATTERN OR PTE FOR POWER TRANSFER EFFICIENCY:
>PTE

 INPUTS FOR THE EFFICIENCY PROGRAM BEGIN:


 ALL THE FOLLOWING QUESTIONS SHOULD BE  ANSWERED IN YES OR NO OR GIVE THE DATA:

 DO YOU WANT BASELINE NUMBER OF POWER DENSITY STEP?
>YES

 DO YOU WANT THE BASELINE CURRENT TAPER?
>YES

 DO YOU WANT THE BASELINE NUMBER OF SLOTS PER POWER RING?
>YES

 DO YOU WANT BASELINE NUMBER OF SLOTS PER  SUBARRAY IN EACH POWER RING?
>YES

 DO YOU WANT THE SAME LOCATION JITTER ON THE  RADIATING ELEMENTS IN ALL POWER RINGS?
>YES

 ENTER THE COMMON LOCATION JITTER OF THE RADIATING ELEMENTS IN TERMS OF  % OF LAMBDA:
>0.0

 DO YOU WANT THE SAME LOCATION JITTERS ON THE CONJUGATION POINTS IN ALL THE POWER RINGS?
>YES

 ENTER THE COMMON LOCATION JITTER OF THE  CONJUGAION POINTS IN ALL THE POWER RINGS IN % OF LAMBDA:
>0.0

 IN EACH POWER RING THE MEAN X AND MEAN Y  TILTS WILL BE ASSUMED SAME:

 DO YOU WANT SAME MEAN VALUES FOR X AND Y TILTS IN DIFFERENT POWER DENSITY RINGS?
>YES

 ENTER THE COMMON MEAN X AND Y TILTS  IN MINUTES:
```

```
>

0.0

DO YOU WANT SAME TILT JITTERS FOR THE  SUBARRAYS IN ALL POWER RINGS?
>YES

ENTER THE COMMON TILT JITTERS IN MINUTES FOR SUBARRAYS IN THE SPACETENNA:
>0.0

DO YOU WANT THE SAME AMPLITUDE JITTER FOR ALL THE POWER RINGS?
>YES

ENTER THE COMMON AMPLITUDE JITTER OF  ALL THE AMPLIFIERS IN PER UNIT VALUE:
>0.0

ENTER THE TOTAL PHASE JITTER IN DEGREES  AT THE END OF PHASE DISTRIBUTION TREE:
>10.0

ENTER THE PILOT WAVE DIRECTIONS, THETA IN MINUTES AND PHI IN DEGREES:
>0.0,0.0

INPUTS FOR POWER RECEIVED CALCULATIONS:

DO YOU WANT THE BASELINE LIMITS  FOR THE THETA INTEGRATION?
>YES

DO YOU WANT THE BASELINE LIMITS FOR THE PHI INTEGRATION?
>YES

ENTER THE NUMBER POINTS PER INTERVAL FOR THETA AND PHI INTERVALS:
>4,4

ENTER THE NUMBER OF INTERVALS TO BE CONSIDERED FOR THE THETA AND PHI RANGES:
>3,3

THETAR =  .00000000    PHIR =  .00000000
M(I) =        395        526        607        729       1002       1335       1618       1821       2427       3632
N(I) =    3918749    9968491    9376400    9145204   12558637   14414030    9667592    8912205   15316727   14970175
NA(I) =      9936      18960      15456      12560      12544      10800       5976       4896       6312       4112
R(I) =   .9776+02   .1773+03   .2318+03   .2747+03   .3203+03   .3658+03   .3960+03   .4219+03   .4630+03   .5000+03
SIGPSI(I)=  .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000
SIGPHI(I)=  .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000
SIGMAI(I)=  .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000
CURNT(I)=  .1000+01   .9129+00   .8164+00   .7454+00   .6666+00   .5773+00   .5000+00   .4714+00   .4083+00   .3333+00
XMEAN(I)=   .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000      .0000
```

```
        83399615.00000000

  INPUTS FOR THE TOTAL POWER RADIATED CALCULATIONS:

  ENTER THE LOWER AND UPPER LIMITS FOR THE  THETA INTEGRATION IN MINUTES:
>0.0,3.0

  ENTER THE NUMBER OF INTERVALS TO BE  CONSIDERED FOR THE THETA RANGE:
>6

                .00000000

        84128013.00000000    3491363.65625000
        87619376.00000000

        81940746.00000000    7940756.18750000
        89881502.00000000

       -81940732.00000000   -7940755.12500000
       -89881487.00000000

              14.87500000

        87619390.00000000

  IN WHAT FOLLOWS ENTER ONLY ONE NUMBER DIFFERENT  FROM 1 EXCEPTING THAT ALL THE NUMBERS SHOULD BE  EQUAL TO 0 TO STOP THE RUN

  ENTER THE NUMBER OF PHASE JITTERS,NUMBER OF  LOCATION JITTERS ON RADIATING ELEMENTS  NUMBER OF LOCATION JITTERS ON RECEIVING
  ELEMENTS AND THE NUMBER OF AMPLITUDE JITTERS
>15,1,1,1

  ENTER THE INITIAL CONDITIONS FOR ALL THE PARAMETERS  IN THE ORDER: LOCATION JITTERS ON TRANSMITING ELEMENTS
  (% OF LAMBDA), LOCATION JITTERS ON RECEIVING ELEMENTS (% OF LAMBDA), AMPLITUDE JITTERS (%),
  PHASE JITTER (DEGREES) DELETING THE INPUT FOR THE SELECTED VARIABLE
>0.0,0.0,0.0
```

```
ENTER THE STARTING POINT AND STEP OF THE VARIABLE
>0.0,1.0

LOCATION JITTERS ON THE RADIATING ELEMENTS (% OF LAMBDA) =      .00000
LOCATION JITTERS ON THE RECEIVING ELEMENTS (% OF LAMBDA) =      .00000
AMPLITUDE JITTERS (PERCENT) =      .00000
```

TOTAL PHASE ERROR (DEGREES)	POWER TRANSFER EFFICIENCY (PERCENT)
.000000	93.317617
1.000000	93.289032
2.000000	93.203333
3.000000	93.060678
4.000000	92.861331
5.000000	92.605657
6.000000	92.294124
7.000000	91.927310
8.000000	91.505885
9.000000	91.030617
10.000000	90.502372
11.000000	89.922109
12.000000	89.290871
13.000000	88.609797
14.000000	87.880099

```
IN WHAT FOLLOWS ENTER ONLY ONE NUMBER DIFFERENT  FROM 1 EXCEPTING THAT ALL THE NUMBERS SHOULD BE  EQUAL TO 0 TO STOP THE RUN

ENTER THE NUMBER OF PHASE JITTERS,NUMBER OF  LOCATION JITTERS ON RADIATING ELEMENTS  NUMBER OF LOCATION JITTERS ON RECEIVING
ELEMENTS AND THE NUMBER OF AMPLITUDE JITTERS
>1,1,15,1

ENTER THE INITIAL CONDITIONS FOR ALL THE PARAMETERS  IN THE ORDER: LOCATION JITTERS ON TRANSMITING ELEMENTS
(% OF LAMBDA), LOCATION JITTERS ON RECEIVING ELEMENTS (% OF LAMBDA), AMPLITUDE JITTERS (%),
PHASE JITTER (DEGREES) DELETING THE INPUT FOR THE SELECTED VARIABLE
>0.0,0.0,0.0

ENTER THE STARTING POINT AND STEP OF THE VARIABLE
>0.0,1.0

LOCATION JITTERS ON RADIATING ELEMENTS  (% OF LAMBDA) =      .00000
AMPLITUDE JITTERS (PERCENT) =      .00000
PHASE JITTER (DEGREES) =      .00000
```

LOCATION JITTERS ON RECEIVING ELEMENTS (% LAMBDA)	POWER TRANSFER EFFICIENCY(PERCENT)
.000000	93.317617
1.000000	92.947852
2.000000	91.847372
3.000000	90.042274
4.000000	87.574899
5.000000	84.502152
6.000000	80.893323
7.000000	76.827454
8.000000	72.390455
9.000000	67.672101
10.000000	62.763028
11.000000	57.751907
12.000000	52.722888
13.000000	47.753426
14.000000	42.912538

```
IN WHAT FOLLOWS ENTER ONLY ONE NUMBER DIFFERENT  FROM 1 EXCEPTING THAT ALL THE NUMBERS SHOULD BE  EQUAL TO 0 TO STOP THE RUN

ENTER THE NUMBER OF PHASE JITTERS,NUMBER OF  LOCATION JITTERS ON RADIATING ELEMENTS  NUMBER OF LOCATION JITTERS ON RECEIVING
ELEMENTS AND THE NUMBER OF AMPLITUDE JITTERS
>1,15,1,1

ENTER THE INITIAL CONDITIONS FOR ALL THE PARAMETERS  IN THE ORDER: LOCATION JITTERS ON TRANSMITING ELEMENTS
(% OF LAMBDA), LOCATION JITTERS ON RECEIVING ELEMENTS (% OF LAMBDA), AMPLITUDE JITTERS (%),
PHASE JITTER (DEGREES) DELETING THE INPUT FOR THE SELECTED VARIABLE
>0.0,0.0,0.0

ENTER THE STARTING POINT AND STEP OF THE VARIABLE
>0.0,1.0

LOCATION JITTERS ON PECEIVING ELEMENTS  (% OF LAMBDA) =     .00000
AMPLITUDE JITTER (PERCENT) =     .00000
PHASE JITTER (DEGREES) =     .00000
```

LOCATION JITTERS ON RADIATING ELEMENTS (% OF LAMBDA)	POWER TRANSFER EFFICIENCY(PERCENT)
.000000	93.317617
1.000000	92.226175
2.000000	89.075887
3.000000	84.205667
4.000000	78.085267
5.000000	71.216358
6.000000	64.052283
7.000000	56.952698

8.000000	50.171278
9.000000	43.865514
10.000000	38.116630
11.000000	32.951161
12.000000	28.359710
13.000000	24.311372
14.000000	20.763932

```
IN WHAT FOLLOWS ENTER ONLY ONE NUMBER DIFFERENT  FROM 1 EXCEPTING THAT ALL THE NUMBERS SHOULD BE  EQUAL TO 0 TO STOP THE RUN

ENTER THE NUMBER OF PHASE JITTERS,NUMBER OF  LOCATION JITTERS ON RADIATING ELEMENTS  NUMBER OF LOCATION JITTERS ON RECEIVING
ELEMENTS AND THE NUMBER OF AMPLITUDE JITTERS
>1,1,1,15

ENTER THE INITIAL CONDITIONS FOR ALL THE PARAMETERS  IN THE ORDER: LOCATION JITTERS ON TRANSMITING ELEMENTS
(% OF LAMBDA), LOCATION JITTERS ON RECEIVING ELEMENTS (% OF LAMBDA), AMPLITUDE JITTERS (%),
PHASE JITTER (DEGREES) DELETING THE INPUT FOR THE SELECTED VARIABLE
>0.0,0.0,0.0

ENTER THE STARTING POINT AND STEP OF THE VARIABLE
>0.0,1.0

LOCATION JITTERS ON RADIATING ELEMENTS  (% OF LAMBDA) =     .00000
LOCATION JITTERS ON RECEIVING ELEMENTS  (% OF LAMBDA) =     .00000
PHASE JITTER (DEGREES) =     .00000
```

AMPLITUDE JITTERS ON CURRENTS	POWER TRANSFER EFFICIENCY(PERCENT)
.000000	93.317617
1.000000	93.308236
2.000000	93.280093
3.000000	93.233231
4.000000	93.167700
5.000000	93.083582
6.000000	92.980979
7.000000	92.860010
8.000000	92.720821
9.000000	92.563577
10.000000	92.388465
11.000000	92.195687
12.000000	91.985474
13.000000	91.758063
14.000000	91.513721

```
IN WHAT FOLLOWS ENTER ONLY ONE NUMBER DIFFERENT FROM 1 EXCEPTING THAT ALL THE NUMBERS SHOULD BE EQUAL TO 0 TO STOP THE RUN

ENTER THE NUMBER OF PHASE JITTERS,NUMBER OF LOCATION JITTERS ON RADIATING ELEMENTS NUMBER OF LOCATION JITTERS ON RECEIVING
ELEMENTS AND THE NUMBER OF AMPLITUDE JITTERS
>0,0,0,0

 CPU TIME USED (MINUTES) =          13.83649993

DO YOU WANT A FRESH RUN?
>NO
```

3.5 SOLARSIM Subroutine Carrier Tracking Loop (CRTL)

Purpose: The purpose of SOLARSIM subroutine carrier tracking loop is to study the effect of the random various noises and various system parameters such as the filter bandwidth, loop bandwidth and the chip rate on the carrier tracking loop phase error.

Access Command: @ ADD LINCOM.CRTL

Inputs: The question and answer session generates the following inputs:

$f_{3\ dB}$ = RF filter 3 dB bandwidth

δ = Half 3 dB notch frequency normalized to the chip rate

γ = The front end filter null in per unit value

β = PN apparent tracking offset normalized to chip time

M = Code repetition rate

R_c = Chip rate

k_1 = Noncoherent interference coupling coefficient

k_2 = Coherent interference coupling coefficient

It should be noted that the $f_{3\ dB}$ value should be 0.0 when there is no RF filtering before the front end filter. This is provided in the program to account for the filtering effect induced by the waveguides in the subarray. Also the parameter β is not used in the program because it is assumed that there is 10% loss of pwoer due to the code tracking error. The results are rather pessimistic because the code tracking loop can track the code very well.

Output: The computer run of SOLARSIM subroutine CRTL is shown in the following pages.

```
@ADD LINCOM.CRTL
FURPUR 27R3A       E35 SL73R1 01/14/81 18:19:11
READY
FURPUR 27R3A       E35 SL73R1 01/14/81 18:19:23
 15 SYM  14 REL  1 ABS

 ENTER NUMBER OF ELEMENTS OF F3,DELTA,GAMMA BETA,M,RC
>1
>1
>1
>1
>1
>1
 ENTER VALUES FOR RF FILTER 3 DB BANDWIDTH IN FRACTION OF RC-F3: (ONE A LINE)
>0.0
 ENTER VALUES FOR DELTA: (ONE A LINE)
>3.0
 ENTER VALUES FOR GAMMA: (ONE A LINE)
>0.001
 ENTER VALUES FOR BETA: (ONE A LINE)
>0.1
 ENTER VALUES FOR M :
>10000
 ENTER VALUES FOR CHIP RATE IN MHZ (RC): , (ONE A LINE)
>10.0
 ENTER K1
>.01
 ENTER K2 :
>.01

 (FOR THE FOLLOWING,HIT RETURN FOR NOMINAL VALUES, OTHERWISE ENTER DESIRED VALUE)
 ENTER CHIP BIASE IN % (NOMINAL 10)
>
 ENTER LOOP BANDWIDTH IN HZ (NOMINAL 10) :
>
 ENTER TRANSMIT POWER IN KW (NOMINAL 65)
>
 ENTER VALUE FOR DIAMETER OF THE TRANSMIT ANTENNA, AREA IN METERS (NOMINAL 10) :
>

E=     .0000   BL =     10.0000
POWER =    .354045-06
K1 =     .010000K2 =     .010000
GAMMA=    .001000
ALPHA =    .000000
DELTA =   3.000000
BETA =     .10000
M =    10000.0
RC =    10.0000     TC =    .100000-06
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
NEQ=     .728444-12
THREE PARTS OF IF ARE      .56-12     .41-03     .96-03     .14-02
LP =          .744        SIGMA =      .408718

ENTER NUMBER OF ELEMENTS OF P3,DELTA,GAMMA-BETA,M,RC
>0.0

RDER OF DATA IS : DELTA  ALPHA,BETA,GAMMA,K1,K2,IF1,IF2,IF3,IF,LF SIGMA,M,TC,RC

 CPU TIME USED (MINUTES) =       1.17071666
* *FLOATING PT OVRFLO HAS OCCURRED* *
* *REGISTERS HAVE BEEN ZEROED* *
* *DIVIDE CHECK HAS OCCURRED* *
* *REGISTERS HAVE BEEN ZEROED* *
```

3.6 SOLARSIM Subroutine Code Tracking Loop (CDTL)

Purpose: The main purpose of the SOLARSIM subroutine code tracking loop is to study the behavior of the code tracking loop under various noises. The subroutine may be used to produce design values for the code tracking loop such as the arm filter bandwidth or the code loop bandwidth, etc.

Access Command: @ ADD LINCOM.CDTL

Inputs: This program has only three inputs:

B_L = The loop bandwidth in Hz

$F_{3\ dB}$ = One-half 3 dB bandwidth in kHz of the bandpass filter in the code loop arm.

F_d = The dither frequency in kHz.

Note: $F_{3\ dB}$ is half of the 3 dB bandwidth and not the total bandwidth. If this instruction is not followed, erroneous results will be generated.

Output: The following pages show a sample run of the SOLARSIM subroutine CDTL.

```
@ADD LINCOM.CDTL
FURPUR 27R3A        E35 SL73R1 01/14/81 18:47:17
READY
FURPUR 27R3A        E35 SL73R1 01/14/81 18:47:36
 12 SYM  10 REL  1 ABS

 ENTER LOOP BANDWIDTH IN HZ:
>10.0
 ENTER 3-DB-BAND-WIDTH-OF-BANDPASS FILTER IN KHZ
>1.5
 ENTER DITHER FREQUENCY IN KHZ:
>1.0
 ENTER K1 AND K2 IN PER UNIT VALUES:
>0.01,0.01
 K1 =      .01000 K2 =      .01000

 SIGSQ =       .3156528901-01
 COMPUTING THE FIRST TERM:

  TERM1 =      .9864197-15
 CPU TIME USED (MINUTES):     7.00000-04

 COMPUTING SECOND TERM:

 TERM2 =      .2746433-08
 CPU TIME USED (MINUTES):     9.83333-04

 COMPUTING THIRD TERM:

 TERM3 =      .8239300-05
 CPU TIME USED (MINUTES):     1.31667-03

 COMPUTING THE FOURTH TERM:

 TERM4 =    -.7371263-15
 CPU TIME USED (MINUTES):     1.51567-03

 TRACKING SIGMA =      .00908
 CPU TIME USED (MINUTES):     1.63333-03
```